



Juha Tervala

# Export pricing and the cross-country correlation of stock prices



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**Suomen Pankki  
Bank of Finland  
PO Box 160  
FI-00101 HELSINKI  
Finland  
☎ +358 10 8311**

**<http://www.bof.fi>  
E-mail: [Research@bof.fi](mailto:Research@bof.fi)**

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The views expressed in this paper are those of the author and do not necessarily reflect the views of the Bank of Finland.

\* E-mail: [juha.tervala@utu.fi](mailto:juha.tervala@utu.fi)

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# Export pricing and the cross-country correlation of stock prices

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Juha Tervala  
Monetary Policy and Research Department

## Abstract

This study analyses cross-country correlations of stock prices (values of firms) using the basic New Open Economy Macroeconomics model. We show that cross-country correlations of stock prices greatly depend on the currency of export pricing in the case of monetary shocks but not notably for temporary technology shocks. In the case of a money supply shock, the producer (local) currency pricing version of the model generates a negative (positive) cross-country correlation of stock prices.

Keywords: stock prices, international business cycles, open economy

JEL classification numbers: E3, F3, F4, G1

# Vientihinnoittelu ja osakkeiden hintojen korrelaatio maiden välillä

Suomen Pankin keskustelualoitteita 28/2009

Juha Tervala  
Rahapolitiikka- ja tutkimusosasto

## Tiivistelmä

Tutkimuksessa analysoidaan avoimen talouden makromallia käyttäen osakkeiden hintojen (yritysten arvojen) korrelaatiota maiden välillä. Tutkimuksessa osoitetaan, että rahasokkien tapauksessa osakkeiden hintojen korrelaatio maiden välillä riippuu suuresti siitä, missä valuutassa vientihinnat asetetaan. Toisaalta väliaikaisten teknologiasokkien tapauksessa vientihinnoittelun valuutalla ei ole suurta merkitystä osakkeiden hintojen välisen korrelaation kannalta. Jos vientihinnat asetetaan tuottajan (ostajan) valuutassa, rahasokki aiheuttaa negatiivisen (positiivisen) osakkeiden hintojen korrelaation maiden välillä.

Avainsanat: osakkeiden hinnat, kansainväliset suhdannevaihtelut, avoin talous

JEL-luokittelu: E3, F3, F4, G1

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# 1 Introduction

In open economy macroeconomics, economists have often analysed cross-country correlations of output and consumption.<sup>1</sup> A common result is that the cross-country correlation of consumption is higher than that of output. This is inconsistent with empirical evidence showing that output is more highly correlated than consumption across countries (Backus et al, 1992).

Cross-country correlation of stock prices has received less attention despite the fact that many modern macro models with solid microfoundations in firms' optimizing problems could be used to generate predictions of stock prices. If a macro model provides a good description of reality, it should be able to explain – partly – the movements in stock prices.

The main purpose of this paper is to analyse the asset pricing implications of the basic New Open Economy Macroeconomics (NOEM) model. To address this topic I present a standard NOEM model that enables one to study the implications of the currency of export pricing (local versus producer currency pricing) for the cross-country correlations of stock prices. A stock price refers to the net present value of all future profits (dividends) of the firm.

The framework adapted here means that the paper falls in the intersection between finance and international macroeconomics. As emphasised by Dumas et al (2003) macro models typically attempt to explain the observed cross-country correlations of output and consumption without paying attention to equity prices. A finance paper in turn attempts to explain the cross-country correlation of equity prices with an asset pricing model and cash flows to equity that may not be related to output. As Cochrane (2005, 70) has emphasised 'we have only begun to scratch the surface of explicit general equilibrium models – models that start with preferences, technology, shocks, market structure – that can address basic asset pricing and macroeconomic facts'.

Kollmann (2001) analyses – both empirically and theoretically – cross-country correlations of (nominal and real) stock returns and their magnitudes relative to those of output and consumption. In the empirical part of the study, he finds that the cross-country correlation (between US and the other G7 countries) of stock returns is higher than that for output and consumption.

Kollmann (2001) studies the implications of price and/or wage rigidities for cross-country correlations of output, consumption and stock returns. One of the main findings of his paper is that, in the event of a technology or monetary shock (or a combination of them), nominal rigidities imply that cross-country correlations of output, consumption and stock returns are higher than without such rigidities. In this respect, nominal rigidities can improve the ability of open economy models to explain the high cross-country correlations of output, consumption and asset returns observed in the data. The model, however, cannot replicate the observation that the cross-country correlation of stock returns is higher than that of consumption.

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<sup>1</sup>This literature includes Backus, Kehoe and Kydland (1992), Betts and Devereux (2000, 2001), Obstfeld and Rogoff (1995) and Schmidt (2006).

Kollmann (2001) also studies the implications of the currency of export pricing – in the context of simultaneous money supply and technology shocks. He finds that the currency of export pricing has only minor quantitative effects on cross-country correlations of key variables.

Kollmann (2001) extends the basic NOEM framework in several directions, whereas I retain the basic NOEM framework and focus on a question that is left virtually unexplored by him. Namely, I analyse the consequences of the currency of export pricing on the cross-country correlation of stock prices (not stock returns) in the case of non-simultaneous shocks.

It is shown in this paper that the currency of export pricing apparently matters in connection with a monetary shock but not with a temporary technology shock. In the case of producer currency pricing (PCP), a monetary shock generates high negative cross-country correlation of stock prices; with local currency pricing (LCP), the correlation is positive. In addition, with PCP, the cross-country correlation of stock prices is lower than the cross-country correlation of output or consumption. With LCP, the cross-country correlation of stock prices is as high as that of output. When the driving force of the business cycles is a temporary technology shock, the currency of export pricing is nearly irrelevant for the behaviour of stock prices.

The rest of the paper is organised as follows. Section 2 presents the model. Section 3 discusses the choice of numerical values for the parameters of the model. Section 4 discusses the empirical evidence on international business cycles. Section 5 studies the effects of monetary shocks on profits and stock prices. Section 6 analyses the consequences of technology shocks for stock prices. Section 7 concludes the paper.

## 2 Model

The model presented in this paper is a synthesis of those presented in Tervala (2007) and (2009).<sup>2</sup> The focus of this paper is, however, different in that it addresses the effects of economic shocks on stock prices.

The model contains two countries: home and foreign. Firms and households are indexed by  $z \in [0, 1]$ . A fraction  $n$  of households and firms are located in the domestic country and the fraction  $1 - n$  are located in the foreign country. Each firm produces a differentiated good. A fraction  $b$  of the firms can ‘price-to-market’. These firms set their prices in the customers’ currency and are referred to as LCP firms. The rest of the firms, the fraction  $1 - b$ , set their prices in the producers’ currency (PCP firms).

The model is a standard NOEM model, and so only the key equations, vital for understanding the main results, are presented in the main text. Moreover, in the description of the model that follows, the equations for the foreign country are explicitly discussed only if they are not symmetric to those for the home country.

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<sup>2</sup>These models are straightforward extensions of Obstfeld and Rogoff (1995) and especially Betts and Devereux (2000).

## 2.1 Households

The representative domestic household optimizes the intertemporal welfare function

$$U_t(z) = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[ \log C_s + \frac{\chi}{1-\varepsilon} \left( \frac{M_s}{P_s} \right)^{1-\varepsilon} - \frac{\ell_s(z)^2}{2} \right] \quad (2.1)$$

Here,  $E_t$  denotes the expectation formed at time  $t$ ,  $\beta$  is the discount factor,  $C$  is a consumption index,<sup>3</sup>  $P$  is the associated price index<sup>4</sup>,  $M$  is nominal money balances,  $\ell$  the household's labour supply, and  $\chi$  and  $\varepsilon$  are positive parameters.

The household can hold three assets: national money, the only internationally traded asset (a one-period nominal bond that denominated in domestic currency terms), and a stock that represents a claim on the aggregate dividends of all domestic firms. Thus each domestic household owns an equal share of all domestic firms. The stock is not traded within a county or between countries.

The budget constraint is given by<sup>5</sup>

$$M_t + \delta_t D_t = D_{t-1} + M_{t-1} + w_t \ell_t(z) - P_t C_t + \pi_t + P_t \tau_t \quad (2.2)$$

where  $D$  is the household's holding of bonds,  $\delta_t$  is the price of a bond ( $1/(1+i_t)$ ), where  $i$  in the domestic nominal interest rate),  $w$  is the nominal wage,  $\pi$  denotes the dividends (profits) of domestic firms and  $\tau$  denotes government transfers.<sup>6</sup> It is noteworthy that the labour market is perfectly competitive and wages are fully flexible. The assumption of a Walrasian labour market is likely to have important implications for the results of this paper, as discussed below.

Households maximize the utility function subject to the budget constraint. The first order conditions are given by

$$\delta_t P_{t+1} C_{t+1} = \beta P_t C_t \quad (2.3)$$

$$\delta_t P_{t+1}^* C_{t+1}^* S_{t+1} = \beta P_t^* C_t^* S_t \quad (2.4)$$

$$\ell_t = \frac{w_t}{C_t P_t} \quad (2.5)$$

$$\ell_t^* = \frac{w_t^*}{C_t^* P_t^*} \quad (2.6)$$

---

<sup>3</sup>The consumption index is  $C_t = \left[ \int_0^1 c_t(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}$ , where  $c(z)$  is consumption of good  $z$  and the elasticity of substitution between goods is given by  $\theta$ .

<sup>4</sup>The domestic price index is given by  $P_t = \left[ \int_0^n p_t(z)^{1-\theta} dz + \int_n^{n+(1-n)b} p_t^*(z)^{1-\theta} dz + \int_{n+(1-n)b}^1 (S_t q_t^*(z))^{1-\theta} dz \right]$ , where  $p^*(z)$  is the domestic currency price of a foreign good and  $q^*(z)$  is the foreign currency price of that foreign good.

<sup>5</sup>The foreign budget constraint is  $M_t^* + \delta_t \frac{D_t^*}{E_t} = \frac{D_{t-1}^*}{E_t} + M_{t-1}^* + w_t^* \ell_t^*(z) - P_t^* C_t^* + \pi_t^* + P_t^* \tau_t^*$ .

<sup>6</sup>The government budget constraint in per-capita terms is  $\tau_t = \frac{M_t - M_{t-1}}{P_t}$ .

$$\frac{M_t}{P_t} = \left( \frac{\chi C_t}{1 - \delta_t} \right)^{\frac{1}{\varepsilon}} \quad (2.7)$$

$$\frac{M_t^*}{P_t^*} = \left( \frac{\chi C_t^*}{1 - \frac{\delta_t S_{t+1}}{S_t}} \right)^{\frac{1}{\varepsilon}} \quad (2.8)$$

Equations (2.3) and (2.4) are the Euler equations for optimal consumption. In equation (2.4),  $S$  is the nominal exchange rate, defined as the price of the foreign currency in terms of the domestic currency. Equations (2.5) and (2.6) are the optimal labour supply equations, which equate the disutility of supplying an extra unit of labour with the marginal utility of the extra consumption due to the extra labour supply unit. Finally, equations (2.7) and (2.8) show that households' optimal money demand depends positively on consumption and negatively on the interest rate.

## 2.2 Firms

### 2.2.1 Technology

The production function of the representative domestic firm is

$$y_t(z) = a_t \ell_t(z) \quad (2.9)$$

where  $y_t(z)$  denotes the output of firm  $z$ ,  $a_t$  is a technology parameter and  $\ell_t(z)$  is the labour input used by the firm. The level of technology in both countries follow the AR(1) process

$$\hat{a}_t = \rho_a \hat{a}_{t-1} + \sigma_t^a$$

where  $\rho_a$  governs the persistence of a technology shock,  $\sigma_t^a$  is an unpredictable shift in the level of technology, and the hat notation denotes the percentage deviation from the initial steady state.

## 2.3 Profits and demand

Domestic firms minimize their costs,  $w_t \ell_t(z)$ , subject to the production function (2.9). The nominal marginal cost is given by

$$MC_t(z) = \frac{w_t}{a_t}$$

As mentioned, PCP firms set one price for both countries while LCP firms price-discriminate across countries. The notation regarding the prices of individual goods is as follows:  $p$  denotes a domestic currency price,  $q$  denotes a foreign currency price, and an asterisk denotes a price set by a foreign firm. For instance,  $p(z)$  is the domestic currency price of domestic good and  $q^*(z)$  is the foreign currency price of a foreign good. For domestic LCP firms, total

output,  $y_t(z)$ , is divided between output sold in the home country,  $x_t(z)$ , at price  $p_t(z)$  and output sold in the foreign country,  $v_t(z)$ , at price  $q_t(z)$ .

The profits of firms are given by

$$\pi_t^{PCP}(z) = p_t(z) y_t(z) - w_t \ell_t(z) \quad (2.10)$$

$$\pi_t^{LCP}(z) = p_t(z) x_t(z) + S_t q_t(z) v_t(z) - w_t \ell_t(z) \quad (2.11)$$

$$\pi_t^{*PCP}(z) = q_t(z^*) y_t^*(z^*) - w_t^* \ell_t^*(z^*) \quad (2.12)$$

$$\pi_t^{*LCP}(z) = (p_t^*(z) v_t^*(z)) / S_t + q_t^*(z) x_t^*(z) - w_t^* \ell_t^*(z) \quad (2.13)$$

Equations (2.10) and (2.11) are the profits of a domestic PCP firm and of a LCP firm, respectively. Equations (2.12) and (2.13) show the profits of a foreign PCP firm and of a LCP firm, respectively. For domestic LCP firms, total output,  $y_t^*(z)$ , is divided between output sold in the home country denoted by  $v_t^*(z)$  at price  $p_t^*(z)$  and output sold in the foreign country  $x_t^*(z)$  at price  $q_t^*(z)$ .

The demands for the goods are given by

$$y_t(z) = \left( \frac{p_t(z)}{P_t} \right)^{-\theta} n C_t + \left( \frac{p_t(z)}{S_t P_t^*} \right)^{-\theta} (1-n) C_t^* \quad (2.14)$$

$$x_t(z) = \left( \frac{p_t(z)}{P_t} \right)^{-\theta} n C \quad (2.15)$$

$$v_t(z) = \left( \frac{q_t(z)}{P_t^*} \right)^{-\theta} (1-n) C_t^* \quad (2.16)$$

$$y_t^*(z) = \left( \frac{S_t q_t^*(z)}{P_t} \right)^{-\theta} n C_t + \left( \frac{q_t^*(z)}{P_t^*} \right)^{-\theta} (1-n) C_t^* \quad (2.17)$$

$$v_t^*(z) = \left( \frac{p_t(z^*)}{P_t} \right)^{-\theta} n C_t \quad (2.18)$$

$$x_t^*(z) = \left( \frac{q_t^*(z)}{P_t^*} \right)^{-\theta} (1-n) C_t^* \quad (2.19)$$

Equation (2.14) gives the demand for a domestic PCP firm. Equations (2.15) and (2.16) give the demands for a domestic LCP firm in the domestic and foreign market, respectively. The corresponding foreign equations are (2.17)–(2.19).

### 2.3.1 International price setting

Under perfectly flexible prices, a domestic LCP firm would maximize  $\pi_t^{LCP}(z)$  with respect to  $p_t(z)$  and  $q_t(z)$ , so that

$$p_t(z) = S_t q_t(z) = \frac{\theta}{\theta - 1} M C_t(z) \quad (2.20)$$

In the absence of price rigidities, the price is simply a constant markup over marginal cost.

In the short run prices are sticky, as in Calvo (1983). In any given period, a firm may set a new price with probability  $1 - \gamma$ , independently of the amount of time since the last adjustment. Thus, there is a probability  $0 < \gamma < 1$  that the firm will not be able to revise its price setting decision. So the firm maximizes the present value of profits with future profits weighted by the probabilities that the price cannot be changed. For example, a domestic LCP firm seeks to maximize

$$\max_{p_t(z), q(z)} V_t^{LCP}(z) = E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} \pi_t^{LCP}(z)$$

where  $\zeta_{s,t} = \prod_{j=s}^t (1 + i_j)^{-1}$  is the domestic nominal discount factor between period  $t$  and period  $s$ . The result is

$$p_t(z) = \left( \frac{\theta}{\theta - 1} \right) \frac{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} C_s \left( \frac{1}{P_s} \right)^{-\theta} MC_s(z)}{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} C_s \left( \frac{1}{P_s} \right)^{-\theta}} \quad (2.21)$$

$$q_t(z) = \left( \frac{\theta}{\theta - 1} \right) \frac{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} C_s^* \left( \frac{1}{P_s^*} \right)^{-\theta} MC_s(z)}{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} C_s^* \left( \frac{1}{P_s^*} \right)^{-\theta} S_t} \quad (2.22)$$

Equations (2.21) and (2.22) give the pricing rules for a domestic good sold in the home and foreign country respectively. The latter equation shows that the exchange rate pass-through to export prices is zero, for those LCP goods whose prices cannot be adjusted.

A domestic PCP firm maximizes

$$\max_{p_t(z)} V_t^{PCP}(z) = E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} \pi_t^{LPCP}(z) \quad (2.23)$$

The result is the same as for equation (2.21), except that the price depends on world demand, not solely on domestic demand. Thus domestic PCP firms that are not able to set new prices let the foreign currency prices of their goods move one-to-one with the exchange rate.

The maximization problem of a foreign LCP firm is

$$\max_{p_t(z), q^*(z)} V_t^{*LCP}(z) = E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} \pi_t^{*LCP}(z)$$

The first-order conditions for this firm are

$$p_t^*(z) = \left( \frac{\theta}{\theta - 1} \right) \frac{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* C_s \left( \frac{1}{P_s} \right)^{-\theta} w_s^*}{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* C_s \left( \frac{1}{P_s} \right)^{-\theta} \frac{1}{S_s}} \quad (2.24)$$

$$q_t^*(z) = \left( \frac{\theta}{\theta - 1} \right) \frac{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* C_s^* \left( \frac{1}{P_s^*} \right)^{-\theta} w_s^*}{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* C_s^* \left( \frac{1}{P_s^*} \right)^{-\theta}} \quad (2.25)$$

Equations (2.24) and (2.25) show the pricing rules for foreign goods sold in the home and foreign country, respectively.

Finally, a foreign PCP firm maximizes

$$\max_{p_t^*(z)} V_t^{EU-PCP}(z) = E_t \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* \pi_t^{EU-PCP}(z) \quad (2.26)$$

The result is virtually the same as (2.25), except that the price depends on world demand, not solely on foreign demand.

### 2.3.2 Staggered price setting and profits

Assume that all firms in the home country are symmetric and every firm that changes its price in any given period chooses the same price and output. The adopted price-setting framework implies that in each period a fraction  $1 - \gamma$  of firms sets a new price while the rest keep their price unchanged.

Following the standard routine in the NOEM literature, the model is log-linearized around a symmetric steady state. Consequently, the solution is expressed as percentage deviations from the initial equilibrium.

The percentage change in the aggregated profits of domestic PCP firms, taking into account nominal rigidities, is given by

$$\hat{\pi}_t^{PCP}(z) = \hat{b}_t(z) + \hat{y}_t(z) - \hat{w}_t - \hat{\ell}_t(z) \quad (2.27)$$

where

$$\hat{b}_t(z) = (1 - \gamma) \sum_{s=t}^{\infty} \gamma^{s-t} \hat{p}_s(z) \Rightarrow \hat{b}_t(z) = \gamma \hat{b}_{t-1}(z) + (1 - \gamma) \hat{p}_t(z) \quad (2.28)$$

In the case of the Calvo-weighted price indexes, the notation is as follows. The indexes  $b$  without an asterisk denote domestic currency prices and the indexes with an asterisk denote foreign currency prices; and the letter  $z$  without an asterisk denotes the price index of domestic goods and  $z^*$  denotes the price index of foreign goods. Thus  $\hat{b}(z)$  is the Calvo-weighted price index of domestic goods, expressed in domestic currency terms. In equation (2.28), the optimal price,  $\hat{p}_t(z)$ , is determined by the solution to equation (2.23), and is given by

$$\hat{p}_t(z) = \beta \gamma \hat{p}_{t+1}(z) + (1 - \beta \gamma)(\hat{w}_t - \hat{a}_t) \quad (2.29)$$

Loosely speaking, equation (2.29) is a new Keynesian Phillips curve that shows that today's optimal price depends on all future marginal costs.

The aggregate profit of domestic LCP firms is

$$\hat{\pi}_t^{LCP}(z) = n(\hat{b}_t(z) + \hat{x}_t(z)) + (1 - n)(\hat{S}_t + \hat{b}_t^*(z) + \hat{v}_t(z)) - \hat{w}_t - \hat{\ell}_t(z) \quad (2.30)$$

where

$$\hat{b}_t^*(z) = \gamma \hat{b}_{t-1}^*(z) + (1 - \gamma) \hat{q}_t(z) \quad (2.31)$$

Equation (2.31) is the the Calvo-weighted price index for domestic LCP goods (expressed in foreign currency). In equation (2.30), the term  $\hat{b}_t(z) + \hat{x}_t(z)$  is referred to as ‘revenue from domestic sales’ and the term  $\hat{S}_t + \hat{b}_t^*(z) + v_t(z)$  is referred to as ‘revenue from foreign sales’. It is noteworthy that the latter is also measured in domestic currency. The change in total revenue must be the population-weighted average of changes in revenue.

The aggregate profit of foreign PCP firms is

$$\hat{\pi}_t^{*PCP}(z) = \hat{b}_t^*(z^*) + \hat{y}_t^*(z) - \hat{w}_t^* - \hat{\ell}_t^*(z) \quad (2.32)$$

where

$$\hat{b}_t^*(z^*) = \gamma \hat{b}_{t-1}^*(z^*) + (1 - \gamma) \hat{q}_t^*(z) \quad (2.33)$$

Equation (2.33) is the Calvo-weighted price index of foreign goods, expressed in foreign currency terms.

Finally, the aggregate profit of foreign LCP firms is given by

$$\hat{\pi}_t^{*LCP}(z) = n(\hat{b}_t(z^*) + \hat{v}_t^*(z) - \hat{S}_t) + (1 - n)(\hat{b}_t^*(z^*) + \hat{x}_t^*(z)) - \hat{w}_t^* - \hat{\ell}_t^*(z) \quad (2.34)$$

where

$$\hat{b}_t(z^*) = \gamma \hat{b}_{t-1}(z^*) + (1 - \gamma) \hat{q}_t^*(z) \quad (2.35)$$

In equation (2.34), the term  $\hat{b}_t(z^*) + \hat{v}_t^*(z) - \hat{S}_t$  is referred to as ‘revenue from domestic sales’ and the term  $\hat{b}_t^*(z^*) + \hat{x}_t^*(z)$  as ‘revenue from foreign sales’. Equation (2.35) shows the Calvo-weighted price index of foreign LCP goods sold in the home country, in domestic currency.

### 2.3.3 Value of the firm

In this paper I assume that the *change* in a domestic firm’s current value is equal to the change in the net present value of all of its future profits (dividends). The periodic change in the value of a domestic firm,  $\hat{A}_t$ , is

$$\hat{A}_t^i = \sum_{s=t}^{\infty} \beta^{s-t} \hat{\pi}_s^i \quad (2.36)$$

where  $i = LCP, PCP$ . The discount rate of households ( $\beta$ ) represents their required rate of return per period.<sup>7</sup> For concreteness, the value of the firm is referred to as the stock price, even though there is no stock market to define the price of the stock. Thus the stock price represents the virtual (ex-dividend) price that would prevail in a stock market where the price of the stock is the net present value of all future profits.

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<sup>7</sup>It is worth noting that the profits are not discounted with a stochastic discount factor. It is, however, likely that using a different discount factor would have only a negligible effect on the main results of this paper. One reason for this is that the change in the real interest rate is quite small.



## 2.4 Equilibrium

The budget constraint of the government and equations (2.10) and (2.11) can be substituted into the household budget constraint (equation 2.2) to derive the consolidated budget constraint of the domestic economy:<sup>8</sup>

$$\delta_t D_t = D_{t-1} + (1 - b) p_t(z) x_t(z) + b [p_t(z) x_t(z) + E_t q_t(z) v(z)] - P_t C_t \quad (2.37)$$

As usual, consider the symmetric initial steady state for the initial net foreign assets that must be zero. The optimal labour supply (2.5), the pricing rule (2.20) and the production function (2.9), normalizing the initial technology level to unity, imply that

$$\bar{y}_0 = \bar{\ell}_0 = \left( \frac{\theta - 1}{\theta} \right)^{\frac{1}{2}} \quad (2.38)$$

where the 0 subscript on barred variables denotes the initial steady state.

## 3 Choice of parameter values

The reasoning behind the choice of numerical values for the parameters is the following. This paper focuses on analyzing the consequences of shocks for the value of the firm as determined by future dividends. Dividends are normally paid once a year and so it is natural to interpret periods as years. Thus the discount factor ( $\beta$ ) is set at 0.95.

The elasticity of substitution between goods is set at 6, which implies a 20 per cent mark-up, consistent with the estimates of Rotemberg and Woodford (1995). The consumption elasticity of money demand ( $1/\varepsilon$ ) is chosen to be 1, which is roughly consistent with the estimates of Mankiw and Summers (1986). The fraction of firms that cannot set new prices in any given period,  $\gamma$ , is set at 0.5. This implies that the average price duration of two years is longer than suggested by recent empirical evidence (see eg Bils and Klenow, 2004). However, price rigidities are essential for monetary policy to have real effects in sticky price models and the same value of  $\gamma$  is also used in many other NOEM models (eg in Sutherland, 1996). The countries are of equal size ( $n = 0.5$ ). To highlight the implications of international price setting on stock prices, I focus on two extreme cases. The first is that all firms use PCP ( $b = 0$ ) and the second is that all firms use LCP ( $b = 1$ ).<sup>9</sup>

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<sup>8</sup>The corresponding foreign equation is

$$\begin{aligned} -\frac{n}{1-n} \delta_t \frac{D_t}{E_t} &= -\frac{n}{1-n} \frac{D_{t-1}}{E_t} + (1-b) p_t^*(z) y_t^*(z) \\ &\quad + b \left[ q_t^*(z) x_t^*(z) + \frac{p_t(z^*) v_t^*(z^*)}{S_t} \right] - P_t^* C_t^*. \end{aligned}$$

<sup>9</sup>I simulate the model using the algorithm developed by Klein (2000) and McCallum (2001).

## 4 Stylized facts

Kollmann (2001) studies the stylized facts of international business cycles that are relevant for the theme of this paper. He uses data from the US and the rest of the G7 countries (referred to as the G6) for the period 1973:Q1–1993:Q3.<sup>10</sup> Table 1 presents some of his key results. It shows that the standard deviations of nominal stock returns are somewhat higher than those of the nominal exchange rate and much higher than those of output (real GDP) and consumption (private non-durables plus services consumption). Kollmann’s (2001) results also show that the cross-country correlation (between US and the G6) of stock returns is higher than those of output and consumption.

Table 1. **Standard deviations of key variables and their cross-country correlations, source: Kollmann (2001)**

Standard deviations (in %):	US	G6
Output	1.83	1.09
Consumption	0.96	0.6
Nominal exchange rate	7.33	
Nominal stock return	8.16	7.8
Cross-country correlations:		
Output	0.61	
Consumption	0.34	
Nominal stock returns	0.73	

It is noteworthy that Kollmann (2001) focuses on stock returns, while the focus here is on stock prices. The volatility of stock prices is however very identical to that of stock returns. For example, Obstfeld and Rogoff (1996, 626) write that: ‘nominal exchange rates typically are *less* volatile than [...] national stock-price indexes’. Finally, Thorbecke (1997) provides evidence that positive monetary policy shocks, measured by innovations in the federal funds target rate and nonborrower reserves, increase stock returns.

## 5 Monetary shocks, profits and asset prices

In this section, the consequences of a monetary shock for stock prices are analysed. A monetary shock is a simple shock to the money supply that follows an AR(1) process

$$\hat{M}_t = \hat{M}_{t-1} + \sigma_t^M \quad (5.1)$$

where  $\sigma_t^M$  is an unpredictable change in the money supply.

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<sup>10</sup>‘The time series for the G6 are weighted averages of time series for each of the G6 countries, using as weights the shares of these countries in total G6 output, in 1980 (for [...] stock returns, a weighted arithmetic average is used; for the remaining variables, a geometric average is used)’ (Kollman 2001, 1565).

## 5.1 Profits and asset prices under PCP

I begin by studying the effects of a monetary shock on stock prices in the basic (Obstfeld-Rogoff) case, where all firms use PCP. Perhaps needless to say, this case have been frequently analysed in the NOEM literature.<sup>11</sup> And since the only innovation of this paper is to study the consequences of shocks for profits and the value of firms, only these topics are discussed.

Consider an unexpected one per cent increase in the domestic money supply ( $\sigma_t^M = 1$ ) in period 1. The results for this case are presented in Figure 1. In all figures, the vertical axes show percentage deviations from the initial steady state.

Figure 1: Monetary shock – producer currency pricing

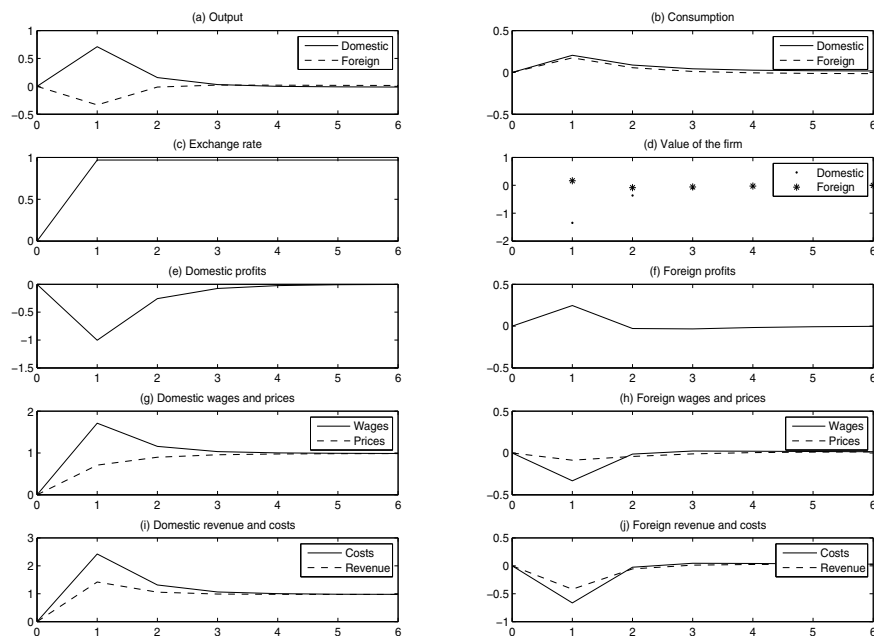


Figure 1 and Table 2 highlights two noteworthy results regarding the ability of open economy models to explain movements in stock prices. First, panel (d) and table 2 show that a monetary shock generates negative cross-country correlation of stock prices. Secondly, the model predicts that stock prices in both countries are counter-cyclical in the short run. In the home country, a boom is associated with falling stock prices. Falling stock prices are inconsistent with the evidence showing that monetary shocks increase stock returns. In the foreign country, stock prices are counter-cyclical, as foreign stock prices increase when foreign output falls.

<sup>11</sup>See Obstfeld and Rogoff (1995, 1996), Betts and Devereux (2000), Sutherland (1996) and Tervala (2009).

There are two important factors behind the results. The first is the expenditure-switching effect of a change in the nominal exchange rate<sup>12</sup> and the second is the combination of sticky prices and flexible wages.

Panel (b) illustrates that a money shock lowers the nominal exchange rate. The assumption of staggered price setting does not change the fundamental equation governing the adjustment of the exchange rate in the PCP version of the model. Thus the change is the same as in the Obstfeld-Rogoff model (see also Obstfeld and Rogoff 1995, 640)

$$\hat{S}_t = (\hat{M}_t - \hat{M}_t^*) - \frac{1}{\varepsilon}(\hat{C}_t - C_t^*) \quad (5.2)$$

This equation demonstrates that the increase in the relative domestic money supply must lower the exchange rate. This lowers the relative price of domestic goods, shifting global demand toward domestic goods away from foreign goods, as long as prices are sticky. This expenditure-switching effect induces an increase in domestic output and a decrease in foreign output.

The counter-cyclical movement of stock prices in the home country is – of course – caused by falling profits (see panel (e)). The combination of sticky prices and flexible wages implies that wages adjust immediately to the increased labour demand and the money supply, but the prices of domestic goods gradually move toward the new level. This is clearly shown in panel (g). The increased labour demand and higher wages imply that the increase in costs (defined as  $\hat{w} + \hat{\ell}$ ) is much larger than the increase in revenue (defined here as  $\hat{b}_t(z) + \hat{y}_t(z)$ ), as shown in panel (i). As the profits of domestic firms fall, domestic stock prices must fall as well.

The combination of flexible wages and sticky prices is the cause of the counter-cyclical movement of stock prices also in the foreign country. The fall in the demand for foreign goods implies less demand for labour, which in turn lowers wages. A fall in the nominal wage and in employment induce a decrease in costs, as panel (j) illustrates. Staggered price setting means that it is not optimal to lower prices much following a temporary drop in demand. Due to the sluggish response of prices, the decrease in revenue is smaller than that of costs. Thus the combination of sticky prices and flexible prices implies that the profits of foreign firms increase. This causes an increase in stock prices in the short run.

Table 2 presents correlation coefficients between some key variables of the models, based on the first six time periods (including the ‘zero period’). The table shows that the cross-country correlation of stock prices is negative and that stock prices are less correlated than are consumption and output. It also illustrates that stock prices are highly counter-cyclical in both countries.

**Table 2. Correlations between key variables, PCP**

$Corr(\hat{y}, \hat{y}^*) = -0.99$	$Corr(\hat{C}, \hat{C}^*) = 0.99$	$Corr(\hat{A}^{PCP}, \hat{A}^{*PCP}) = -0.80$
$Corr(\hat{y}, \hat{A}^{PCP}) = -0.99$	$Corr(\hat{y}^*, \hat{A}^{*PCP}) = -0.90$	

<sup>12</sup>A country with a depreciating currency ... will experience a fall in the relative price of its exports and a resulting redirection of world expenditure in favor of its products’ Obstfeld and Rogoff (2000, 120).

Table 3 gives the standard deviations for output, consumption, stock prices and the exchange rate, based on the first six time periods. It illustrates that the standard deviation of stock prices in the home country is greater than that of the exchange rate, which accords with the empirical evidence. Moreover, the empirical results of Kollmann (2001) show that the exchange rate is less volatile than stock returns but more volatile than output. Loosely speaking, the model is in tune with this finding in that stock prices are more volatile than the other variables in the home country. In the foreign country, the standard deviation of stock prices is smaller than those of output and the exchange rate.

**Table 3. Standard deviations of key variables, PCP**

	Output	Consumption	stock prices	Exchange rate
Home country	0.26	0.071	0.49	0.36
Foreign country	0.13	0.068	0.081	

Kollmann (2001) develops a model to explain cross-country correlations of output, consumption and equity returns. His main focus is on how nominal rigidities can enhance the ability of open economy model to capture empirically observed cross-country correlations. His main finding is that nominal rigidities (stickiness of prices and/or of wages) is helpful in explaining observed cross-country correlations, but along the way he deals with a number of questions that are directly related to the theme of this paper.

The results of this paper are somewhat difficult to compare with those of Kollmann (2001), as he extends the basic NOEM basic in several directions, while I retain the basic framework. He assumes that each country produces a single final good and intermediate goods. The single final good, which is not internationally traded, can be consumed or used as an investment good. There is, however, monopolistic competition in the intermediate goods market and these goods are internationally tradable. Firms that produce intermediate goods use domestic physical capital and labour as inputs. The price of the final good is flexible, while prices of intermediate goods are set in a staggered fashion, in terms of the currency of the producer. In addition, wages are also set in a staggered fashion.

Kollmann (2001) finds that cross-country correlations of output, consumption and nominal stock returns are all positive (in the range of 0.41-0.59). The notable difference is that cross-country correlations of output and stock prices are negative in the present model. Schmidt (2006) argues that the positive spill over effect of a domestic shock on foreign output found by Kollmann (2001) is caused by the low values of consumption and interest elasticities of money demand. An alternative explanation is that Kollmann (2001) sets the elasticity of substitution between domestic and foreign intermediate goods at one, which implies that the expenditure-switching effect is virtually absent, unlike in the present model. This may partly explain the difference in the cross-country correlation of output. In addition, Kollmann (2001) does not analyse a simple permanent domestic monetary shock but rather a more complex shock where the domestic shock is temporary and domestic and foreign shocks are correlated.

The differences in cross-country correlations of stock prices/returns are likely to be caused by the nature of the shock and the structure of nominal rigidities. As explained above, the assumption of flexible wages and sticky prices implies that profits are counter-cyclical in this model. In the model of Kollmann (2001), the combination of sticky wages and prices implies that stock returns are pro-cyclical in both countries immediately after the shock and counter-cyclical after that. Thus the cross-country correlation of stock returns is positive.

## 5.2 Profits and asset prices under LCP

Betts and Devereux (2000, 2001) demonstrate that a critical factor for the international transmission of monetary shocks is the pricing currency. In the case of LCP, the present model is almost identical to Betts and Devereux (2000)<sup>13</sup> and completely identical to Pierdzioch (2004) and Tervala (2009). The only innovation with this version is to analyse the consequences of a monetary shock for profits and stock prices.

In this case, the prices of imported goods, whose prices cannot be adjusted, are not influenced by a change in the exchange rate in the short run. So the pass-through of exchange rate changes to import prices is zero in the short run. Exchange rate movements, by contrast, directly affect firms' revenues at given output levels.

The impulse responses of key variables to a monetary shock are shown in Figure 2. A monetary shock increases demand in the home country. In the absence of both home bias in consumption and an expenditure switching effect, the increased demand is equally split between the countries. Thus output increases by the same amount in both countries, as in Betts and Devereux (2000).

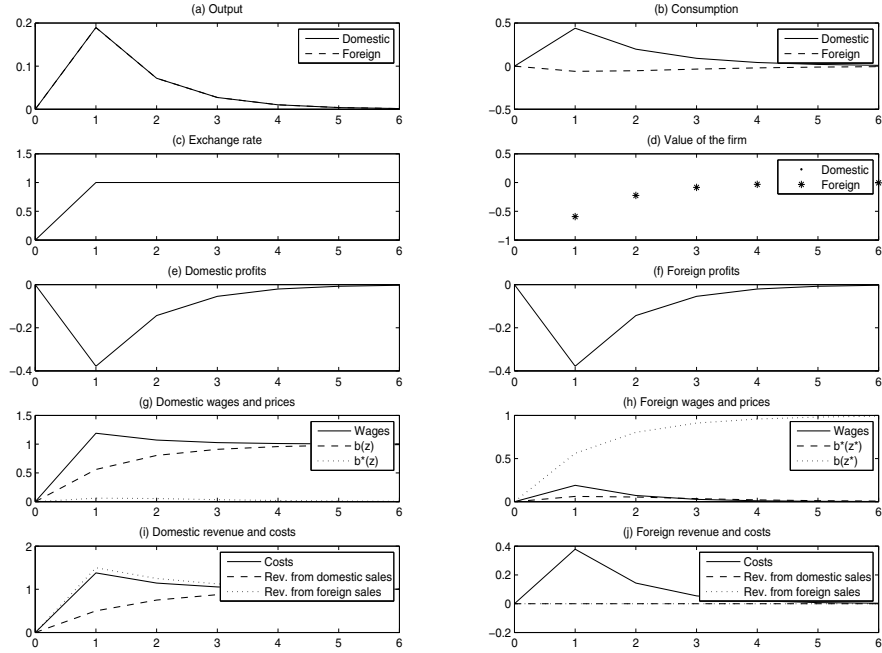
As in the case of PCP, a domestic money supply change induces an exchange rate depreciation. This increases domestic firms' revenue from foreign sales (measured in domestic currency terms), as equation (2.30) shows. Panel (i) shows that revenue from foreign sales increases by more than costs. An increase in the money supply and in the demand for labour create upward pressure on wages. The increase in costs due to higher wages and employment is, however, smaller than the increase in the revenue from foreign sales. Thus the profits from foreign sales increase.

Panel (i) also shows that the increase in revenue from domestic sales is smaller than the increase in costs. As in the case of PCP, the nominal wage responds immediately whereas the price response is sluggish. Thus the profits from domestic sales fall. In addition, this effect dominates the increase in profits from foreign sales. The total profit of domestic firms therefore decreases. This implies that stock prices fall, as shown in panel (d)<sup>14</sup>, causing stock prices to be counter-cyclical in the home country. In addition, the result is

<sup>13</sup>The only difference is the extra dynamics caused by the staggered price setting.

<sup>14</sup>In panel (d) of Figure 2, the small dots that show domestic share prices are hidden behind asterisks, as share prices are perfectly correlated.

Figure 2: Monetary shock – local currency pricing



inconsistent with the empirical finding that monetary shocks increase stock returns.

Panels (a) and (f) of Figure 2 show that stock prices are counter-cyclical also in the foreign country. Panel (j) shows a surprising result: the fall in profits is caused by an increase in costs and not by a fall in revenue. Equation (2.34) shows, firstly, that the exchange rate depreciation reduces the revenue that foreign firms earn on goods sold in the home country. Secondly, the rise in the price of foreign goods sold in the home country increases revenue. Thirdly, higher exports by foreign firms increase their revenues. Panel (j) shows that the first effect is exactly offset by the second and third effects, so that revenue from domestic sales does not fall.

Panel (j) illustrates that revenue from sales in the foreign country also remains constant. Recalling equation (2.34), the increase in the Calvo-weighted price of foreign goods,  $\hat{b}_t^*(z^*)$ , boosts revenue, but this effect is exactly offset by a drop in sales in the foreign country ( $\hat{x}_t^*(z)$ ). In the special case of  $\varepsilon = 1$ , the fall in  $\hat{x}_t^*(z)$  is the mirror image of the increase in  $\hat{b}_t^*(z^*)$ . Therefore, revenues from foreign sales do not change. Panel (j) shows that the reason for the drop in foreign profits is the increase in costs caused by increases in wages and in employment. This drop in profits implies a fall in stock prices.

Table 5 shows that the asset-pricing implications of the LCP model are mixed. In the special case of  $\varepsilon = 1$ , stock prices are perfectly correlated across countries. If  $\varepsilon \neq 1$ , the correlation is not perfect, but still very high. This is consistent with the empirical evidence in that if stock prices are highly

correlated across countries, then stock returns must be highly correlated. Table 5 shows that the correlation coefficient between output and stock prices is -1 in both countries.

Table 4. **Correlations of key variables, LCP**

$Corr(\hat{y}, \hat{y}^*) = 1$	$Corr(\hat{c}, \hat{c}^*) = -0.9$	$Corr(\hat{A}, \hat{A}^*) = 1$
$Corr(\hat{y}, \hat{A}^{LCP}) = -1$	$Corr(\hat{y}^*, \hat{A}^{*LCP}) = -1$	

It is worth remembering that in this model firms do not hedge their foreign exchange rate exposure. In practise, firms can insulate their profits from short-run exchange rate fluctuations by hedging. In addition, as emphasised by Engel (2000, 1452), shareholders are typically uninformed of the firm's foreign exchange exposure and 'the markets are not aware of significant gains or losses on foreign exchange markets until annual reports are compiled. So, even if the firm has not fully protected itself against foreign exchange fluctuations, the shareholders may not realize this and fail to adjust fully their assessment of the value of the firm'.

Table 7 shows that the standard deviation of stock prices in both countries is greater than those of output and consumption but smaller than the standard deviation of the exchange rate. In this respect, the model does not accord with the empirical evidence, according to which the volatility of stock prices is higher than that of the exchange rate.

Table 5. **Standard deviations of key variables, LCP**

	Output	Consumption	stock prices	Exchange rate
Home country	0.069	0.16	0.22	0.38
Foreign country	0.069	0.24	0.22	

Kollmann (2001, section 4.3.2.1) analyses the implications of the currency of export pricing but predominantly for simultaneous money supply and technology shocks. He finds that the currency of export pricing has relatively weak quantitative effects on cross-country correlations of key variables. But more importantly, he analyses (very briefly) the implications of LCP in the context of a monetary shock. It seems that the currency of export pricing has quantitative implications for cross-country correlations of output and consumption whereas the cross-country correlations of asset returns seem unclear.<sup>15</sup> In this paper it is shown that in the basic NOEM model, where the expenditure-switching effect is relatively strong, the currency of export pricing has qualitative implications for the cross-country correlation of stock prices.

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<sup>15</sup>In the case of a monetary shock, Kollmann (2001) includes only a figure (figure 3 on page 1579) from which it is difficult to say whether the cross-country correlation of stock returns is negative or positive.



## 6 Technology shocks and stock prices

Since the publication of an influential paper by Kydland and Prescott (1982), the proponents of Real Business Cycle (RBC) theory have supported the view that technological changes are the driving force behind business cycles, at least in developed countries. The next step is to study the consequences of technology shocks on stock prices.

In much of the RBC and New Keynesian literature, the persistence of a technology shock is set at 0.95 for quarterly time periods. In this paper, however, the periods are years. So I set  $\rho_a = 0.8$ . In addition, the shock to the level of domestic technology is set at one per cent ( $\sigma_t^a = 1$ ).

### 6.1 Profits and asset prices under PCP

Figure 3 presents the dynamic responses of key variables to a temporary technology shock in the case of PCP. A technology shock increases the potential level of production, leading to an increase in domestic production. As emphasised by Gali (1999), however, the presence of sticky prices implies that the increase in demand is smaller than that of technology. Employment thus falls in the short run, as shown in panel (g).<sup>16</sup> A technology shock lowers the marginal costs of domestic firms. Domestic prices start to fall, which induces an increase in demand. Output therefore peaks in the second period. When the technology shock fades out, the economy gradually moves toward the new steady state.

A technology shock lowers the relative price of domestic goods, even in the short run, despite the exchange rate appreciation.<sup>17</sup> The domestic terms of trade thus deteriorate. The domestic terms of trade is here the relative price of domestic goods in terms of foreign goods. The change in the terms of trade is then defined as  $\hat{b}_t(z) - \hat{S}_t - \hat{b}_t^*(z^*)$ . So the first term (the fall in the price of domestic goods) dominates the latter two (the exchange rate appreciation and the fall in the price of foreign goods). Thus the exchange rate appreciation does not cause an expenditure-switching effect. Instead domestic firms, with lower marginal costs, grab a bigger share of both the home and foreign market. Consequently foreign output decreases and domestic output increases in the short run.

Panel (e) shows that a domestic technology shock boosts the profits of domestic firms. First, immediately after the shock, a fall in employment and in the nominal wage reduces costs. In addition, higher production more than offsets the revenue loss caused by falling prices. Thus domestic firms' revenues increase. The fall in costs and increase in sales imply an increase in short-term profits.

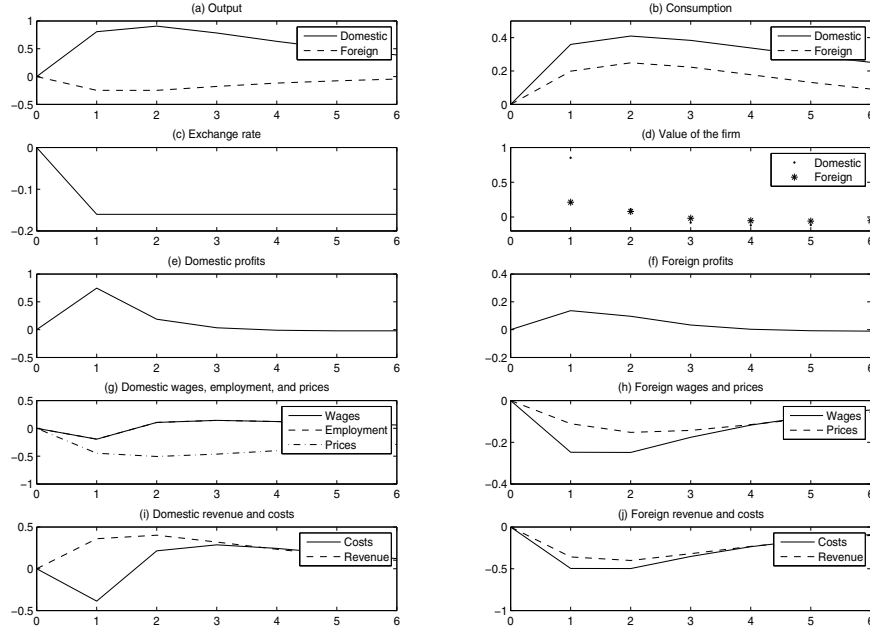
In the medium run, the increase in domestic output is larger than in technology. Higher employment and wages imply that costs become higher

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<sup>16</sup>Note that in case of  $\varepsilon = 1$  the responses of employment and the nominal wage are identical.

<sup>17</sup>The exchange rate appreciates because there is a permanent increase in relative domestic consumption.

Figure 3: Technology shock – producer currency pricing



than revenues. Thus panel (i) shows a drop in profits in the medium run. The substantial short-term profits, however, more than offset all the forthcoming losses. Domestic stock prices thus rise in the short run, making stock prices pro-cyclical in the short run. However, stock prices fall below the initial valuation in the medium run.

Panels (a), (d) and table 8 show that stock prices are counter-cyclical in the foreign country. As mentioned, domestic firms, with higher productivity, can sell their goods cheaper, thus reducing the demand for foreign goods. The combination of flexible wages and sticky prices implies that the fall in wages is sudden, whereas that in prices is sluggish. Thus costs fall by more than revenue, causing an increase in foreign firms' profits in the short run, as shown in panel (f). This is reversed in the medium run, but the present value of profits is positive. Consequently, stock prices increase in the short run, making them counter-cyclical. As in the case of the home country, stock prices fall in the medium run.

Table 7 illustrates that in the case of a technology shock, the PCP version is consistent with the empirical observation that the correlation of stock prices is high and positive across countries. The table also shows that the cross-country correlation of consumption is as high as that of stock prices. It is a standard finding in an open economy model that the results provide for more risk sharing than is found in the data.

Table 6. **Correlations of key variables, PCP**

$Corr(\hat{y}, \hat{y}^*) = -0.93$	$Corr(\hat{C}, \hat{C}^*) = 0.96$	$Corr(\hat{A}^{PCP}, \hat{A}^{*PCP}) = 0.96$
$Corr(\hat{y}, \hat{A}^{PCP}) = 0.36$	$Corr(\hat{y}^*, \hat{A}^{*LCP}) = -0.72$	

Table 10 demonstrates that the standard deviation of stock prices is higher than any other key variables in both countries. The table also shows the basic model with a simple technology shock does not capture well the empirical regularities.

Table 7. **Standard deviations of key variables, PCP**

	Output	Consumption	stock prices	Exchange rate
Home country	0.31	0.14	0.35	0.061
Foreign country	0.098	0.086	0.099	

The results of Kollmann (2001) are somewhat different from those of the present model. He finds that cross-country correlations of key variables are positive and that a technology shock increases output and consumption in both countries. The differences in results are caused not only by the above-mentioned factors, such as the structure of nominal rigidities and the strength of the expenditure-switching effect, but also by the fact that in his model a domestic technology shock raises the level of foreign technology with a lag.

## 6.2 Profits and asset prices under LCP

Figures 3 and 4 show that the international transmission of a temporary technology shock is not sensitive to the currency in which prices are set. The behaviours of output, consumption and stock prices are qualitatively the same in both cases. A temporary technology shock has a relatively weak effect on the exchange rate. Thus the impact of the expenditure-switch (or lack of it) on the results is relatively weak.

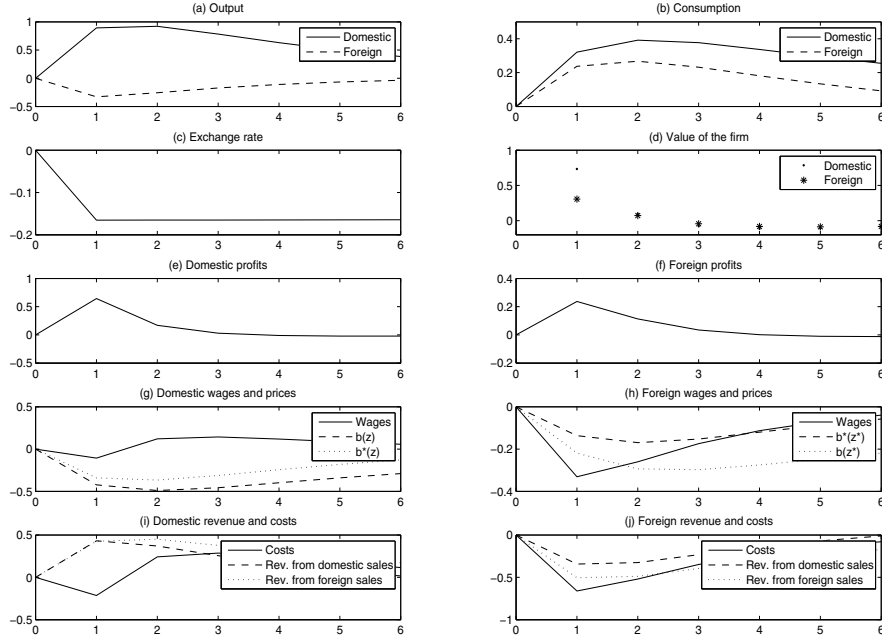
Table 8. **Correlations of key variables, LCP**

$Corr(\hat{y}, \hat{y}^*) = -0.90$	$Corr(\hat{c}, \hat{c}^*) = 0.92$	$Corr(\hat{A}, \hat{A}^*) = 0.98$
$Corr(\hat{y}, \hat{A}^{LCP}) = 0.44$	$Corr(\hat{y}^*, \hat{A}^{*LCP}) = -0.80$	

Table 9. **Standard deviations of key variables, LCP**

	Output	Consumption	stock prices	Exchange rate
Home country	0.33	0.13	0.31	0.062
Foreign country	0.12	0.095	0.14	

Figure 4: Technology shock – local currency pricing



## 7 Conclusions

This paper shows that the cross-country correlations of stock prices (values of firms) greatly depend on the currency of export pricing in the case of monetary shocks but not notably for temporary technology shocks. For instance, if monetary shocks are the driving force behind the business cycle, the PCP (LCP) version of the basic NOEM model predicts that stock prices are negatively (positively) correlated across countries.

The paper shows that there are a number of features in the data that no version of the model can explain for the case of simple monetary and technology shocks. But how is one to evaluate the importance of these results? The masters of NOEM modelling, Obstfeld and Rogoff (1996, 625) have written: ‘Prescott (1986) has expressed the view that the difficulties of explaining asset price fluctuations are such that macroeconomic models should be judged mainly on their ability to explain fluctuations in output, consumption, investment, and in other real quantity variables’. Indeed, if one adopts the view of Prescott, the results of this paper have little significance. The opposite view is expressed by Cochrane (2005), who argues that macroeconomists cannot simply dismiss asset market data. Under the latter view, the results of this paper have more significance.

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P.O.Box 160  
**FI-00101** HELSINKI  
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